



## MEMORANDUM

DATE: August 26, 2003

TO: Distribution

FROM: William L. Stockho, PuSPS Project Manager, T371H, X4749

SUBJECT: PLUTONIUM STABILIZATION AND PACKAGING PROJECT (PuSPS)  
LESSONS LEARNED – WLS-002-03

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Attached is the final compilation of lessons learned from the PuSPS Project. The issues and recommendations reflect input solicited from PuSPS supervisors and operators, Project Engineering, Campaign Planning, Quality Assurance, Project Management, Subject Matter Experts, and all support groups. No attempt has been made to prioritize the recommendations, and the issues are presented in no particular order.

On July 16, 2003, PuSPS was formally declared complete, culminating 25 months of production operations. Over the life of the project, 1,895 3013 containers were generated in compliance with the DOE Standard. An additional 651 containers were generated that were rejected for various reasons and had to be reworked.

Questions should be directed to Bill Stockho at extension 4749.

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## **PuSPS Project Lessons Learned and Recommendations**

### **Criticality Safety**

1. Numerous controls, especially procedural controls, were not directly required by the Criticality Safety Evaluation (CSE). Well over 100 procedural controls were formally identified for PuSPS operations, which was a significant burden to operations.  
Recommendation: Establish procedural controls only if driven by the CSE.
2. Routine glovebox filter change activities were not accommodated by the CSE, resulting in significant operational impact for daily filter changes.  
Recommendation: Address routine maintenance activities in the CSE.
3. Application of the total mass limits for metal and oxide was very simple and user friendly.  
Recommendation: Wherever possible, establish a simple total mass control, avoiding complex multi-conditional controls.
4. Having a single and simple limit for our airlocks saved us numerous times when the process got "backed up". This provided a place to hold/stage in-process material during recovery, etc.  
Recommendation: If possible, establish locations within the process where a simple, easy to understand control is in place.
5. Initial training for criticality safety was judged to be excellent, and the criticality safety engineer communicated with operations personnel during development of the CSE.  
Recommendation: Early involvement and routine interaction between operations and criticality safety engineering is highly recommended.

### **Radiological Safety**

1. Work processes and materials changed several times during the life of the project.  
Radiological Safety should have used these changes as opportunities for thorough in-process ALARA Job Reviews.  
Recommendation: Utilize in-process ALARA job reviews to reduce worker exposures.
2. Although the majority of the material processed through the system had relatively low dose rates (<10 mrem/hr @ 30 cm), later material exhibited significant neutron and gamma fields (e.g., 300 mrem/hr @ 30 cm, 1200 mrem/hr on contact). Work practices were not geared toward high dose rate material, and considerable changes were required for ALARA purposes.  
Recommendation: Anticipate elevated dose rate material and plan accordingly. Even though the run of "hot" material was short compared to the life cycle of the process, doses were significantly increased as a result.
3. When stabilizing feed material with beryllium present, the project observed an increase in the neutron radiation dose after the material was stabilized at 1000 °C. This was attributed to oxidation of the beryllium metal that changed the geometry of the beryllium, effectively increasing the number of target sights available for the plutonium/beryllium alpha-neutron reaction. In some cases, the neutron dose from the loaded furnace tray increase by a factor of

four after stabilization. This phenomenon had not been observed at Rocky Flats during production days when lower stabilization temperatures were used. Thus, the increase in neutron dose is attributed to the higher stabilization temperatures required by DOE Standard 3013. These higher temperatures apparently allow the beryllium to be oxidized in addition to the plutonium.

Recommendation: DOE should evaluate the merits of stabilizing beryllium-bearing oxides at lower temperatures to prevent the oxidation of beryllium and avoid the increased neutron dose rates. This would require that a technical equivalency to the standard be demonstrated (such as the reduced temperature approved for the chloride bearing oxides) or a change to the 3013 standard. The impact from the Be contaminated oxides was communicated to other DOE sites that may have similar material.

4. Pre-operational reviews resulted in a requirement to conduct contamination surveys of each Inner Can inside the Fume Cabinet. The survey was conducted using five swipes, three for the Inner Can and two for the Fume Cabinet. This requirement became problematic when high dose rate cans were processed. It was eventually determined that the Inner Can and Fume Cabinet could be adequately surveyed using two swipes assuming that the area swiped was 100 cm<sup>2</sup>. This resulted in conservative estimates of contamination levels because the area actually swiped was greater than 100 cm<sup>2</sup>.

Recommendation: Carefully evaluate any recommendation that increases contact time with material. Consider the impact that would occur if dealing with high dose rate cans.

5. Standard DOT shipping regulations allow for dose rates up to 200 mrem/hr on the surface of the conveyance. DOE-specific requirements were more restrictive, allowing 200 mrem/hr only on the surface of the shipping container. Additional shielding on the shipping container to reduce dose rates was not allowed. These requirements were not communicated to project operations until after a substantial number of high dose rate 3013's had been produced. The more restrictive limit required these cans to be reworked leading to increased dose to workers. Recommendation: Ensure that planning personnel are aware of the more restrictive DOE requirements.

6. The procedures were initially written such that material could not be re-worked until after it had completed the entire stabilization and packaging process. This required extensive handling of the material. To minimize increased exposures, the procedures were eventually changed to allow rework at various stages of the process. Oxide convenience cans were surveyed before being passed to the packaging system to estimate the dose rate that would occur after placement into the shipping container at the end of the process. Cans with excessive dose rates were reworked before leaving the stabilization system and not subjected to the remainder of the process.

Recommendation: Make allowances to catch cans requiring re-work as early in the process as possible.

7. The dynamic nature of the process required significant amounts of feed material to be staged for processing. Completed 3013's, waiting for non-destructive testing, were placed in the same staging areas used for the feed material. This accumulation of radioactive material in the rooms used for processing caused unwarranted increases in area dose rates. The situation was exacerbated by the proximity of the material staging areas to Material Security Team personnel. Extensive shielding efforts were required to reduce exposures.

Recommendation: Material staging areas should be planned with ALARA considerations in mind.

8. At the initiation of the project a major radiological concern was migration of contamination across the sphincter seal into the Fume Cabinet. To minimize contamination migration, oxide convenience cans were wiped with a wet wipe prior to transferring to the packaging system. While this reduced the migration of contamination from the furnace glovebox to the sphincter seal, it created two additional problems. It increased the moisture levels in the furnace glovebox where oxide moisture samples were taken and it required additional handling of the convenience cans resulting in increased operator exposure.

Recommendation: Future projects of this type should evaluate the potential for the migration of contamination and, where possible, implement methods to reduce the migration without requiring manual intervention by the operators. Using a bagless transfer system and GTA welder for Inner Cans (like that used at Hanford and Savannah River) should significantly reduce this concern.

### **Industrial Safety**

1. The Job Hazards Analysis (JHA) was extremely thorough and had lots of input from operations on proper controls to mitigate hazards.

Recommendation: Continue operator involvement in developing the controls for process hazards.

2. Airlocks were designed with moving shelves, intended to assist operators in moving materials from one glovebox to another. Rather than help, the moving shelves were an ergonomic disadvantage, as they would try to move out from under any item being placed onto them. Also, the requirement to center the shelf prior to closing airlock doors was a nuisance.

Recommendation: Airlocks used for material pass through should have a stationary shelf, or a simple lock mechanism to hold the shelf in place during loading. During the design phase, the system should be reviewed to identify those locations where automation provides a small advantage. It may be better not to implement automation in those locations to keep the system simple for the operators.

3. Ergonomics in the stabilization box were not very good in some places, particularly the sampling station and the rework station (band saw for cutting cans). This was due in part to the process being defined after the design was complete.

Recommendation: Define process as much as possible early in the design phase.

### **Training**

1. The certification packages developed for the stabilization process and packaging process included numerous classroom and On the Job Training (OJT) requirements. Consequently, the certification process for operators and supervisors typically required several weeks, even months, to complete. Eventually, the certification requirements for Packaging Operator were divided into two separate certifications, one for Field Operator and another for Console Operator. This allowed operators to certify more quickly and enabled operators to be more productive while completing their remaining certifications.

Recommendation: Operator certification requirements should be divided into small, logically grouped classroom and OJT requirements, allowing operators to complete a few limited certifications and then perform limited operations on watch while completing the remainder of the certifications, as necessary.

2. Training and OJT conducted prior to startup were very effective, enabled by an adequate schedule (several weeks dedicated to OJT on the actual equipment) and a dedicated operations manager to lead the training effort.  
Recommendation: For complex processes such as this, allow adequate training time and require senior leaders to train key personnel.
3. After the initial startup, training resources were trimmed such that little support was provided for continuing and new operator training. Based on the lengthy training requirements, this burdened supervisors, who were already fully challenged by daily operations, with significant fieldwork and paperwork. The training effectiveness was reduced and the average time for trainees to qualify increased.  
Recommendation: For processes with significant training requirements and likely personnel turnover, maintain a dedicated trainer.
4. Data collection and paper documentation were a significant activity in the PuSPS process, yet little or no specific training was developed to assist operators in understanding how to complete the paperwork. This resulted in paper errors that required correction later. When this problem was recognized, more extensive training on data collection and documentation was incorporated into the preparations for startup of the TGA/FTIR process that resulted in fewer paperwork errors for that process.  
Recommendation: For processes in which data collection is significant include specific data collection and documentation training in both initial and continuing training.
5. Campaign Planning personnel were not required to undergo any specific training on the process. As a result, they had limited understanding of the operations being performed and sometimes had difficulty interpreting the data. Operations management answered numerous questions about process flow and reworks, explaining why the data looked as it did. When a major process change was implemented, only a few of the Campaign Planning personnel were trained, leaving others to sort it out on their own.  
Recommendation: Operations management needs to ensure that all Campaign Planning and support personnel who perform data interpretation and product certification are trained to understand the process being performed and receive upgrade training anytime the process changes.

### **Procedure Development and Use**

1. Operator involvement in initial development of procedures was considered a significant advantage.  
Recommendation: Continue to involve experienced operators in procedure development as much as possible.
2. The procedure appendices were used to collect critical certification data, yet were not organized or laid out to simplify data recording. Data fields were located at any point on the page, rather than all data fields aligned on the margin, etc.  
Recommendation: Invest the effort to logically lay out the appendices or other data collection forms, to simplify the completion and review of the data.
3. Operating procedures contained not only process steps, but incorporated numerous requests from other "customers". Examples include recording instrument numbers and calibration dates

for instruments controlled through the RFETS calibration requirements (redundant), etc. This made the procedures more cumbersome, especially Use Category 1 procedures.  
Recommendation: Severely limit the procedure steps to include only key process requirements. Other, nice to have steps should be implemented by other methods instead of the operating procedures.

4. A Weld Process Control Procedure was developed to provide instruction for numerous weld test and diagnostic routines. This procedure was found to be a significant benefit in that it replaced numerous other work control documents that would have provided less clear instruction and more administrative burden.
5. All of the operating procedures were developed and implemented as Use Category 1 procedures, requiring the procedures to be open and followed step-by-step at the work location. The reader/worker process was used to control execution of the procedures. The procedures contained a high level of detail that was helpful in training the operators and preparing for the Operational Readiness Review (ORR). But as the project progressed and operators became more familiar with the procedures, the procedures retained the same level of detail and were never downgraded from Use Category 1. This slowed down operations unnecessarily and occasionally led to mistakes when operators overanalyzed the procedure and took actions without thinking.

Recommendation: Once operators gain proficiency with the operating procedures, the procedures should be revised to eliminate Use Category 1 requirements for all but the most critical sections, and the level of detail should be reduced to take advantage of operator proficiency and allow more flexibility.

6. About two thirds of the way through the project, highlighted texts were added to the procedures to implement the building management's philosophy for controlling use of Use Category 1 procedures using a reader/worker routine. Either the highlighted texts or the detailed steps were to be read by the reader while the reader observed the worker to ensure compliance with the procedure. These highlighted texts did not supercede MAN-066-COOP, Site Conduct of Operations Manual, and procedure steps were still required to be performed as written in the sequence specified. In practice, this change did not improve compliance with procedures and workers sometimes missed steps or performed steps out of order when the reader only read the highlighted text.

Recommendation: The use of highlighted text to simplify the reader/worker routine is not recommended. Instead, once operators gain proficiency with the operating procedures, the procedures should be revised to eliminate Use Category 1 requirements for all but the most critical sections, and the level of detail should be reduced to take advantage of operator proficiency and allow more flexibility. (See Training item 5 above.)

7. Operating procedures changed very little during the first year and a half of the project. Supervisors and operators had made some suggestions for process improvements, but the Project Manager was reluctant to change procedures that had been approved through an ORR. The relieving Project Manager was more receptive to change and many process improvements were implemented in the final seven months. It is likely that the project could have finished earlier with fewer 3013's generated had these changes been implemented sooner.  
Recommendation: Projects need to be receptive to process improvements that benefit cost and schedule. Complicated projects such as this should schedule periodic stand downs to review procedures with operating crews and solicit suggestions for process improvements. The first of these reviews should be scheduled as soon as sufficient operational experience has been

obtained, probably about 3 months after the initial startup. Periodic reviews should continue for the life of the project.

8. PuSPS procedures were used to implement a large number of administrative requirements specified in a broad variety of source documents. These ranged from Authorization Basis controls to commitments made to the DNFSB and DOE during the ORR and included controls required by the Savannah River Site to satisfy their authorization basis for safe storage of the 3013's. A few, but by no means all, of these requirements were marked in the procedures to indicate their source. The project team had to rely on their collective memory to avoid inadvertently changing or deleting these committed steps during subsequent procedure revisions. It would have been helpful to have a matrix that mapped all of the requirements into the procedures, indicated the source of the requirement, and specified the change control authority for each requirement.

Recommendation: During the initial development of procedures, create a separate administrative procedure to promulgate a compliance matrix that identifies all of the requirements with their source, indicates how and where (procedure step) the requirement is implemented, and who has the authority to change each requirement. Update this matrix each time the requirements change or when new requirements are identified. Procedure steps that implement various requirements should be annotated to indicate the source document number (currently only done for criticality safety requirements). This will provide a single document that lists all the requirements and agreements and leaves a paper trail to demonstrate how the requirements are being met.

### **Communication**

1. First line supervision found that the operations chain of command was sometimes ambiguous. The project was extremely dynamic in terms of equipment and process, and was also highly visible at the highest management levels. This led to direction being delivered by the Operations Manager, the Project Manager and on some occasions from the Building 371 Nuclear Operations Manager.

Recommendation: Establish and follow a disciplined chain of command. Ensure supervisors know what to do when they perceive a conflict in direction.

2. Engineering and operations were often out of synch and sometimes adversarial due to lack of communication. Numerous changes prompted by process and equipment conditions were not broadly communicated.

Recommendation: Emphasize communication within key organizations.

3. The Campaign Planning organization (performing a production control function) did not assign staff to be directly on the floor communicating with operations supervisors. This often resulted in delay and confusion regarding specific disposition of certain materials and product.

Recommendation: The staffing of a production control function for a project of this complexity, spanning round-the-clock operations, should include the resources to deploy personnel on the floor during all operating shifts.

4. The daily 0600 operations planning meeting was considered a significant benefit. This allowed supervisors to enter the day's pre-evolution briefing with up to the minute status of equipment, material, and operating plans.

5. The pre-evolution briefings conducted for PuSPS were considered an excellent communications tool.
6. The PuSPS supervisors' log, which included details of process operations and response to anomalies, was an excellent communication tool. However, quality of log entries varied greatly from supervisor to supervisor and most entries lacked sufficient detail to fully understand what happened, particularly during anomalous conditions. Supervisors used these logs primarily to support shift turnover and they were adequate for that purpose. Occasionally, the logs were used to reconstruct events that had happened in the past. In general, the logs lacked sufficient detail to reconstruct those events.  
Recommendation: Especially for complex processes, broaden the scope of log entries and maintain them without fail. Train supervisors on expectations for log keeping and provide written instructions that include sample entries.
7. When the project began, shift-to-shift turnover was conducted on the floor using turnover checklists. Several months into the project, the turnover checklists were eliminated and the quality of shift-to-shift turnover degraded. Shift-to-shift turnover was not always conducted between supervisors on the floor, particularly between the off-going PM shift and the on coming Mid-shift. This resulted in several missed communications and, on at least one occasion, contributed to a criticality safety deficiency.  
Recommendation: Conduct all shift-to-shift turnovers on the floor between supervisors using shift turnover checklists.
8. Material Balance Cards were promulgated in several procedures and, for some gloveboxes, they were relied upon to maintain compliance with criticality safety mass limits. Initially, there was no requirement to audit material balance cards to ensure their accuracy. When a mistake (double entry) on a material balance card for the TGA glovebox led to a criticality safety deficiency, daily audits were implemented.  
Recommendation: Implement frequent audits of material balance cards that are relied on for criticality safety compliance.

### **Equipment**

1. PuSPS glovebox design did not adequately consider the need to access equipment for maintenance, repair, or replacement. Much equipment was too large to be removed through the available bag ports requiring that the equipment be repaired in place. Stabilization furnaces in particular required frequent repair and accessibility was particularly poor.  
Recommendation: All equipment (e.g., scales, furnaces, etc.) should be selected under the assumption that it will have to be repaired and/or replaced during hot operation of the project. Where possible, equipment should be sized to fit through bag ports. Glovebox design should include adequate gloveports for disassembly and repair of equipment and facilitate the installation of new equipment.
2. Precision equipment, such as a balance, was difficult to clean in a plutonium oxide environment. Attempts to clean the equipment were less than satisfactory.  
Recommendation: Air brushes (using helium or argon as required) should be installed in each glovebox that has precision equipment to facilitate cleaning by blowing the appropriate dry gas onto the equipment.



3. Due to the need to provide a laser safety enclosure, equipment inside the fume cabinet could not be viewed during operations. This made troubleshooting difficult when problems occurred inside the fume cabinet.  
Recommendation: Consideration should be given to installing video cameras in those critical locations that cannot be viewed during equipment operation, such as inside laser safety enclosures. The cameras would allow project personnel to see the equipment operating, a significant benefit when troubleshooting problems. These cameras are in addition to the cameras recommended for monitoring the welding processes (see item 5 in the Laser Welding Process section).
4. The furnaces chosen for this project were selected based on their availability rather than their function relative to the process. They were hard to maintain, and had poor operating history.  
Recommendation: Critical equipment such as the stabilization furnaces should be selected based on function ahead of cost.
5. The Central Research Labs (CRL) gloveport design was excellent, avoiding significant time loss for posting the area for all glove and bag changes.
6. The scale in the automated Can Weigh/Cap Insertion glovebox was extremely troublesome and required frequent repair. It was hard to reach and had no provision for loading check weights, which had to be carefully stacked or they would fall and damage the scale.  
Recommendation: Ensure that any scale being used for safeguards accountability purposes is easily accessible for check weighing and repair.
7. Accessibility and lighting inside the inner can weld enclosure (fume cabinet) was deficient. Troubleshooting and maintenance were difficult due to tightly packed equipment.  
Recommendation: Design of the weld enclosure should consider maintainability of the equipment.
8. The dehumidification system did not have the capacity to effectively fulfill its design function.  
Recommendation: Specify and procure critical process systems to be robust.
9. The crusher mechanism installed to minimize waste by compacting metal cans was extremely heavy, never worked, and was so heavy and complex it could not be made operable once in the glovebox.  
Recommendation: Identify the simplest mechanism that can accomplish the objective.
10. The airlocks on the material preparation glovebox were too small to allow passage of replacement balance scales. There were frequent problems with the scales that, fortunately, did not require scale replacement. If replacement had been required, it would have required removing a glovebox window.  
Recommendation: Future designs of this type should ensure that the airlocks are sized to allow passage of critical replacement equipment such as balance scales.
11. When stabilizing oxides of low purity, the furnaces frequently released smoke and particulate effluents into the glovebox, clogging the glovebox exhaust filters. This was true even for oxides that had been pretreated on hot plates. For the last six months of the project, furnace glovebox exhaust filters had to be changed at least daily, sometimes every shift when processing the lower purity oxides. In order to change filters, operations had to be suspended and furnaces had to be off or cooling down. This was a significant impact to operations. The design of the glovebox filters did not allow continued operations while changing the filters. A

design change was developed late in the project that would have installed two sets of filter banks allowing one filter to be changed while the other filter in the bank was still on line. This change was never implemented due to time constraints.

Recommendation: Future designs should allow changing filters without shutting down the process. Having filters installed in banks such that one filter is idle in each bank during normal operations would allow shifting to the idle filter when the on-service filter needed to be changed.

12. The original design of the Packaging System called for nitrogen in the tip/dispense/fill glovebox and helium in the can weigh/cap insertion glovebox. A gaslock was installed between the two boxes to keep the atmospheres separate. The final design and installation called for helium in both gloveboxes, making the gaslock unnecessary, but the gaslock remained installed. Even though some parts of the operating program were modified to simplify the passage of cans through the gaslock, the team experienced numerous gaslock problems during the project that hampered packaging efficiency.  
Recommendation: Future designs should limit the number of gases used to a minimum to avoid the necessity of installing additional equipment that may fail. When design changes are made prior to operations, ensure that unnecessary equipment is removed.
13. The project experienced numerous inner can weld failures that required rework. This reduced process efficiency, used additional can assets that were in short supply, and resulted in increased exposure to operators. The inner can laser welder was difficult to repair and reliability degraded at the end of the project.  
Recommendation: For future projects of this type, strong consideration should be given to using a Gas Tungsten Arc (GTA) welder for the inner cans. This would be similar to the bagless transfer system being used by Hanford and SRS. These welders have consistently produced better inner can welds than the laser and are significantly more reliable. They are also easier to repair.
14. The PuSPS process utilized two chiller systems, neither of which could support all of the process systems.  
Recommendation: Specify chiller systems that can support process functions independently, then utilize the second chiller as a backup. This recommendation should be considered whenever there are two similar pieces of equipment independently performing similar functions within the process.
15. After stabilization the oxide materials were often tightly agglomerated, requiring chisels to break up and release the oxide from the furnace tray. This was especially prevalent when processing lower purity oxides, and posed significant ergonomic risks, radiation dose exposure, and reduced production throughput.  
Recommendation: Consider using a release agent or tray material that will promote release of oxide cake from the pan. Employ a small hammer mill to break up clumps and promote material homogeneity, if required by the process.
16. The data acquisition software for the stabilization system worked unreliably and created numerous problems. Eventually, the project stopped relying on this software and relied on manual data recording only. This complicated procedures and did not entirely avoid the problems, since the software was still necessary for some process operations and could not be removed. Operators experienced frequent difficulty passing cans to the packaging system because the software did not work properly. A small number of cans had to be reprocessed due to the loss of this data.

Recommendation: Future projects should avoid relying on software to record and track data unless absolutely necessary. The amount of data tracked by the software should be kept to an absolute minimum. The PuSPS project lost confidence in the software early in the project and tracked all data by hand. At that point the data tracking software became a hindrance rather than help.

17. The barcode readers were unreliable, frequently failed, and were difficult to repair. The reader in the can weigh/cap insertion glovebox failed early in the project and was never successfully repaired. The original software did not provide for manual entry of can ID numbers. This was eventually modified to allow bypassing at least two barcode readers.

Recommendation: For future projects using barcode readers, ensure that the software accommodates manual entry of the data in order to bypass the readers should they fail.

18. Aluminum coating on the furnace trays was credited with increasing the life of the tray. Even so, trays had to be replaced frequently when processing low purity oxides due to caustic attack caused by impurities in the oxide. In some cases, trays had to be replaced after as few as ten furnace runs. Obtaining new aluminum coated trays was a lengthy process and the project came close to running out of furnace trays on more than one occasion.

Recommendation: Anticipate replacing trays frequently when stabilizing low purity oxides and ensure adequate numbers of trays are available to support the project. Anticipate long lead times when ordering replacement trays. Evaluate using different materials for the furnace trays to increase the life of the trays.

19. The helium re-circulation systems worked extremely well and reliably.
20. The "panelviews", which provided the operator control interface with stabilization processes, worked extremely well and reliably.
21. The design of the Packaging System relied heavily on automation mainly to reduce operator exposure. Before the project began, the team recognized that the equipment in the tip/dispense/fill glovebox would not work reliably, so they changed the process to have oxide convenience cans filled by hand in the furnace glovebox. While this worked well and avoided project down time due to equipment failure, operator dose increased as a result of the change. In general, the design of the packaging equipment was more complicated than it needed to be, contributing to frequent failures and loss of efficiency. The project developed a significant list of "work arounds" to circumvent equipment failures.  
Recommendation: Future projects should limit the use of automation to those functions that are simple and reliable and absolutely necessary. The use of tip/dispense/fill equipment to fill convenience cans was a poor idea and would never have worked. Low purity oxides tended to clump together during stabilization and required considerable manual effort to break up and remove from the furnace tray. Manual operation was probably the only option for handling this material.

## **TGA/FTIR**

1. TGA/FTIR was introduced after the start of the project to perform moisture analysis on low purity oxides after stabilization. Because there was no room in the furnace glovebox, the equipment was located in a separate glovebox that made handling samples awkward. The TGA glovebox included an emergency dump valve for ventilation exhaust that served no useful purpose.

Recommendation: When designing gloveboxes for future projects such as this, provide a glovebox for TGA/FTIR that is attached to the stabilization gloveboxes. This would simplify glovebox design and facilitate transfer of samples and waste. The TGA glovebox should be separated from the furnace glovebox by a door (an airlock is not necessary) to keep the sensitive TGA units isolated from stabilization operations, but still provide for easy transfer of samples and waste.

2. The sample vials used for TGA were made of glass. A number of these vials broke during handling requiring the associated oxide batch to be re-sampled and/or restabilized.  
Recommendation: Evaluate the use of plastic sample vials for TGA or coat the vials with a protective film to preclude breakage.
3. Toward the end of the project, a number of TGA/FTIR samples failed moisture analysis due to what appeared to be re-absorption of moisture in the sample. This primarily showed up in oxides containing chlorides (IDC's 067 and 086) and IDC 159 (screenings from oxide). The exact reason for the failures was never determined. Oxide associated with these failures was re-stabilized. A number of test samples were run at the end of the project to try to determine the mechanisms involved, but the results of those samples are currently unknown.  
Recommendation: Continue to evaluate the reason for these failures and promulgate any lessons learned to projects using TGA, TGA/FTIR or TGA/MS systems.
4. Subject Matter Experts were used extensively to train the first supervisor and operators to qualify on TGA/FTIR. As a result, this team had the highest level of knowledge. When additional supervisors and operators were added, the currently qualified supervisors trained them. This had the effect of diluting the quality of the training, since the qualified supervisors passed on only the information that they thought was important. As more supervisors qualified, the information passed on got further diluted.  
Recommendation: Use subject matter experts to support all of the training, not just the initial group. Require subject matter experts to certify supervisor/operator proficiency as a prerequisite to qualification.

#### **Authorization Basis**

1. Original AB limitations on the number of 3013 containers which could be out of vaults at any given time, and the multiple conditions placed on those containers determining their treatment within AB requirements, was extremely difficult to maintain. Several AB violations resulted.  
Recommendation: Avoid establishment of AB requirements directly related to dynamic product characteristics. Keep AB controls as simple as possible. Avoid administrative controls (procedures) whenever possible.

#### **Safeguards and Security**

1. Material surveillance requirements for PuSPS represented a significant cost in dollars and manpower, with little perceived gain in material safeguards. Two-person dedicated teams surveilled material round-the-clock, while numerous other MST qualified operators were in the area working the material that was being watched. During operations, the material surveillance requirements could be adequately met with personnel performing operations without need for the dedicated two-person team.  
Recommendation: Limit material surveillance requirements to that which are required by order.

### Production Control

1. The utilization of the midnight shift to bag out trash and set up for production on the other two shifts was an excellent strategy.
2. The production control function, i.e. campaign planning, was not defined prior to operations startup, nor did senior management provide focus or attention on this critical function early in operations. There was no clear establishment of roles/responsibilities for material movement and priority. As a result, material feed was sporadic for many weeks, information about material on the floor was not timely, AB requirements which relied on real-time information were compromised, containers were occasionally run through certain operations (such as NDA and NDT) more than once, etc. All management attention was focused on the stabilization and packaging process, leaving other critical processes without definition. Recommendation: All critical functions, which may include support functions, need to have clear roles and responsibilities established up-front by senior management.
3. The project team did not have a full time budget analyst assigned and had limited ability to evaluate all charges against the Project Authorization Directive (PAD). This required considerable effort at the end of the project to try to identify project costs and decide which charges were allocable to the PAD and which charges were legitimately part of the project but not allocable to the PAD.  
Recommendation: For projects where the fee earning potential is tied to a project or PAD cost variance, it is necessary to have the ability to review all charges as they appear in the accounting system, including material costs, to determine charging accuracy and allocability. This requires a dedicated budget analyst, at least part time. Also, it would have helped to have more detail in the PAD concerning charge allocation.

### Stabilization and Packaging Process

1. A process change that was implemented at K-H suggestion, which allowed certain rework containers to be re-packaged without being re-stabilized, was a significant improvement. It allowed higher throughput and avoided wear on furnace equipment.
2. Late in the project, with only a few months remaining, a PuSPS supervisor suggested that we might repair defective inner can welds before performing the leak check. This would save scarce inner can assets. The change was implemented almost immediately and several defective inner can welds (holes visually identified on the weld face and/or the cut face) were repaired by hand welding using a TIG welder before the end of the project. While this suggestion saved numerous inner cans, it is unfortunate that this suggestion wasn't implemented earlier.  
Recommendation: Continue to allow manual weld repair of Inner Cans. Evaluate the use of manual weld techniques to repair Outer Cans that are rejected due to lack of fill. (213 Outer Cans were reworked during the PuSPS project due to lack of fill.)  
*— rework outers outside line?*
3. The original campaign plan called for Campaign Planning to pre-select the feed cans in each batch based on an assumed oxide density and compatible feed IDC's. This was inefficient and resulted in a large number of only partially filled 3013's. The process was eventually changed by assigning each feed can to a compatible feed group and having the foreman or operators

select cans from these groups as necessary for each stabilization batch. The revised process ensured that each oxide convenience can was full to the volume or mass limit. This maximized the use of each 3013 resulting in fewer cans needed to complete the project.

4. When pretreatment operations started, the process required operators in room 3602 to volume limit each oxide batch before thermal pretreatment to ensure that the batch would fit in a 3013. Pretreated batches were then weighed to ensure that the 3013 mass limit would not be exceeded. The pre-batched, pretreated batches were passed to stabilization and dumped directly into a furnace tray without volume limiting. Campaign Planning selected feed items for pretreatment batches based on 3013 limitations. This limited the throughput of the process. The process was eventually changed to maximize the size of each pretreatment batch. Feed items for pretreatment batches were selected based on not exceeding criticality safety mass limits. Volume limiting was no longer performed in Room 3602, but was performed by stabilization operators. This significantly increased pretreatment throughput and helped to ensure that pretreatment would not become the limiting path for project completion. It was also compatible with the process change in stabilization that maximized the use of a 3013 (see item 3 above).
  
5. IDC 159 (screenings from oxide) was a particularly nasty feed material. It was typically characterized by the presence of large quantities of what the operators called "rocks", hard ceramic like material that required considerable effort to break up and size reduce sufficiently to pass through the volume limiter screen. Furthermore, the material produced profuse quantities of smoke when stabilized in a furnace, despite the fact that it had all been pretreated by heating on hot plates to 500 degrees centigrade for two hours before being stabilized. The smoke rapidly clogged the furnace glovebox ventilation exhaust filters (see item 11 in the Equipment section). After stabilization, the oxide frequently failed moisture analysis for reasons that were never really determined. When restabilized, the material continued to smoke, indicating that whatever contaminants were causing the smoke had not been completely burned off during the previous stabilization run. (One batch of this stuff required six stabilization attempts before it passed moisture analysis. It continued to smoke during each and every stabilization run.) The oxide formed a brick-like substance during stabilization that required considerable effort to break up and remove from the furnace tray. And finally, the oxide aggressively attacked furnace trays and TGA equipment.  
 Recommendation: Find another way to get rid of this stuff in the future. DOE should evaluate disposal of this type of material at WIPP. Failing this, the material should be better characterized through R&D to enable stabilization with fewer problems.
  
6. Reducing the stabilization temperature for the chloride bearing oxides significantly minimized the amount of salt volatilized and reduced the furnace glovebox ventilation exhaust filter clogging that would have been experienced had the stabilization temperature remained at greater than 950 °C for this material. The technical equivalency developed for Rocky Flats to reduce the temperature for the chloride bearing oxide was successfully expanded to Hanford, also improving their stabilization and packaging operations.

### **Laser Welding Process**

1. The Data Acquisition System (DAS) automatically captured and recorded power at the laser when welding and cutting the Inner Can and when welding the outer can. It would have been helpful during troubleshooting to have some additional parameters captured by the DAS such

as Inner and Outer Can rotation speed during welding and Outer Can plume jet and shield shoe gas flow rates.

Recommendation: Consider expanding the capability of the DAS to record weld parameters useful for troubleshooting.

2. The location of the Outer Can plume jet was critical to achieving good welds. As designed, it was difficult to get an accurate measurement of the location of the plume jet nozzle support. It was also difficult to adjust the position.

Recommendation: The Outer Can plume jet support should be designed to allow an accurate measurement of its location. Also, a dial adjustment to change the forward/backward and left/right position of the plume jet would be a significant improvement.

3. Tracking and trending of laser power readings (power at laser shutter closed, power at laser during welding, and power at the work piece) provides crucial data that is necessary to make laser power adjustments and to troubleshoot welding problems. This is necessary for both the Inner and Outer Can welders. Project engineers plotted and tracked this data and used it to recommend power adjustments before the welds degraded.

Recommendation: Laser power readings should be tracked for every weld. These readings should be correlated with weld quality to establish an operating band that produces good welds. When power drops near the low end of the band, it's time to adjust the power.

4. The helium flow from the shielding shoes for both the Inner and Outer Can welds is not well controlled. The overall flow rate is controlled, but the distribution of that flow varies significantly because of variations in the density and distribution of the stainless steel wool packed inside the shoe. Experience showed that weld quality was very sensitive to the helium flow distribution across the face of the shield shoe.

Recommendation: For future systems, it is recommended that a testing station be built that will be used for measuring the flow distribution of the gas exiting the shielding shoe. This would enable better reproduction of the flow characteristics that produce good welds. For PuSPS, reproducing the required flow distribution was a hit or miss proposition.

5. PuSPS installed a video camera inside the Outer Can weld chamber that greatly improved the capability to detect off-normal welding operation. It was very useful in troubleshooting Outer Can weld problems. A similar camera was installed in the Fume Cabinet to observe Inner Can welds, but it was not used extensively because the camera was easily bumped out of position during routine maintenance. A piece of filtered welding glass was placed in front of the camera to reduce the light at the lens. A significant improvement would have been to provide a means of remotely removing the dark glass filter to view the weld and set-up when not actually welding.

Recommendation: Future processes employing laser welders should install video cameras inside the weld enclosures to monitor welding operations and performance of the laser. These cameras should be equipped with a remote capability to rotate a filter in front of the lens during welding and remove the filter when not welding.

6. The PuSPS project installed spacers placed between the backstop rollers and the support bracket in the Outer Can weld enclosure that aided in stabilizing the position of the rollers. This resulted in more consistent positioning of the weld.

Recommendation: Install spacers between the backstop rollers and support bracket in Outer Can weld enclosures for future projects.

7. The support structure holding the Outer Can plum jet nozzle and shield gas shoe was not very robust and allowed the plum jet nozzle and shield shoe to change position as cans were welded. In addition, making position adjustments was very difficult.  
Recommendation: Future designs should provide a more robust mounting for the plume jet nozzle and shield shoe and provide for easy adjustment of their positions.
8. In order to improve the likelihood of producing good welds, the project found it necessary to perform frequent "user maintenance" in the Outer Can weld enclosure and the Fume Cabinet. The maintenance consisted of checking shield shoe and plume jet positions, inspecting cover glasses, and cleaning dirt and soot out of the plume jet nozzle as required. Roller-ball assemblies in the Outer Can weld enclosure were also checked to ensure that none had been knocked out of position. The frequency of this maintenance increased over the life of the project until, at the end, it was being performed every 4 to 5 welds. The design of the equipment made it difficult to perform this maintenance. It is likely that other projects employing laser welders will find it necessary to perform similar maintenance.  
Recommendation: The Outer Can weld enclosure should be larger than the current design to make routine testing and maintenance easier. The enclosure should be equipped with access doors instead of bolted panels to simplify access.
9. Both the Inner Can and the Outer Can laser welders produced significant quantities of soot that deposited on the welding components. This soot could cause defective welds, if not removed on a regular basis. The ventilation system was not effective in removing the soot or preventing the soot from depositing in the weld area. Soot tended to build up in the ventilation duct leaving the Outer Can weld enclosure and, if not cleaned regularly, this soot would fall back into the weld area and contaminate the weld.  
Recommendation: Investigate and implement improvements in the ventilation for future systems to improve the flow across the weld area and remove the soot. The ventilation system that serves the Inner Can weld enclosure should be separate from the system that serves the Outer Can weld enclosure so that adjusting one ventilation system does not effect the other. Regardless of the ventilation system design, plan to frequently clean the soot from the weld area and weld components to prevent weld failure.
10. The method of leak testing the Inner Can weld (using the Outer Can as a "bell jar" and making a vacuum seal on the outside of the Outer Can with an O-ring) was a constant problem because the seal with the Outer Can was not dependable. Metal shards produced during the Inner Can cut operation tended to migrate toward the Capslide area and could lodge between the O-ring and the Outer Can when attempting to make the seal. This frequently resulted in a failure of the leak check due to a bad seal. A failure of this leak test (false positive) is very disruptive to the production operation because a time-consuming recovery must be performed whenever a leak is detected in the Inner Can.  
Recommendation: Evaluate more dependable methods of performing the Inner Can leak test and implement for future projects. It would not have been difficult to remove the Inner Can from the Fume Cabinet and place it in a separate leak test chamber (similar to the one used for the Outer Can leak test), since Fume Cabinet entry was required for every can anyway.
11. The PuSPS project found that the Inner Can Fume Cabinet pressure needed to be nominally 1.4 inches (H<sub>2</sub>O) less negative than the Can Weigh/Cap Insertion Box pressure. This prevented sagging of the weld pool, a condition that increased the incidence of holes in the weld.  
Recommendation: Establish a similar control for future projects.



12. The original recommended maintenance frequency for laser power supply de-ionized (DI) water replacement and flash lamp inspection was once every six months. The PuSPS project found it necessary to change DI water and inspect the flash lamps monthly to ensure good welds.  
Recommendation: Increase the frequency for flash lamp inspections and DI water replacement to monthly for future projects using laser welders.
13. On several occasions communication was lost between the Programmable Logic Controller (PLC) and the laser resulting in the failure of the Data Acquisition System (DAS) to update the weld power for welds performed after the failure. The only way to catch the problem was to keep track of the reflected power as indicated at the Plutonium Packaging Control System (PPCS) computer. If the weld power didn't change slightly from weld to weld, the communication had been lost. The computer displayed peak, average, and mean weld power for each weld. The project wrote down all three to compare with the next weld. This avoided welding too many cans before identifying and correcting the communication failure and minimized the number of reworks. Since weld power was an essential variable, those 3013's for which no weld power was recorded had to be reworked. The cause of the communication failure was never conclusively determined. The problem was corrected by rebooting the system.  
Recommendation: If systems similar to PuSPS are used in the future, operators should monitor the displayed weld power for each weld to identify communication failures. All essential variables should be tied to both a digital and an analog recording system. This facilitates troubleshooting of equipment and the redundant system provides backup, which would have avoided the need for some Non-Conformance Reports (NCR's) and reworks over the life of the project.

### **Non-Destructive Weld Testing**

1. The PuSPS project used a camera-based visual inspection station to display a magnified image of the weld on a CRT monitor. Software was used to perform measurements of critical weld dimensions. This system worked very well and was critical to the success of the weld quality program.  
Recommendation: Use a similar system for visual weld inspection on future projects of this type.
2. The PuSPS project added a stereo microscope to the visual inspection procedure to resolve questions regarding suspected defects found with the camera-based system.  
Recommendation: Include the use of a stereo microscope in the inspection procedures for future systems.
3. Dental impression material is used to make a molded impression of each depression on the Outer Can Weld surface. This mold is viewed with the camera and the depth of the depression is measured. It is difficult to orient this mold precisely to ensure that an accurate measurement is made.  
Recommendation: Design a fixture to position and orient the mold for future projects to improve the reliability of the measurement.